P517364.PDF [Page: 3 of 32]

Copy No. 25

DEFENCE R&D DÉFENSE

The Environmental Acoustics Group's Seagoing Measurement Systems

Paul C. Hines

John C. Osler

Daniel L. Hutt

Defence R&D Canada

Technical Memorandum

DREA TM 2001-173

October, 2001

National Defence Défense nationale

Canada

P517364.PDF [Page: 4 of 32]

104-06259/

Copy No: _____

The Environmental Acoustics Group's Seagoing Measurement Systems

Paul C Hines

John C. Osler

Daniel L. Hutt

Defence Research Establishment Atlantic

Technical Memorandum

DREA TM 2001-173

October, 2001

517364.PDF [Page: 5 of 32]

Author

Paul C. Hines, John C. Osler, Daniel L. Hutt

Approved by

Paul C. Hines

A/Head Underwater Acoustics

Approved for release by

Kirk Foster

DRP Chair

© Her Majesty the Queen as represented by the Minister of National Defence, 2001

© Sa majesté la reine, représentée par le ministre de la Défense nationale, 2001

Abstract

During the past few years, the Environmental Acoustics group has developed and/or acquired a number of large scale purpose built systems to support underwater acoustics research at DREA The systems fall into two categories those used to make acoustic measurements of the parameters of interest, and those used to make environmental support measurements Due to the size and complexity of these systems and their potential use both in house and in collaborative trials it is important that their functionality and deployment be documented This memorandum describes these tools for potential users, outlines the launch procedure for each system, and highlights typical acoustic applications

Résumé

Au cours des dernières années, le groupe de l'acoustique environnementale a mis au point ou acquis un certain nombre de systèmes sur mesure à grande échelle dans le but d'appuyer les activités de recherche au CRDA Les systèmes sont regroupés dans deux catégories, soit les systèmes utilisés pour effectuer des mesures acoustiques des paramètres d'intérêt, et les systèmes utilisés pour prendre des mesures environnementales à l'appui des activités acoustiques En raison de la taille et de la complexité des systèmes et de leur utilisation potentielle à la fois sur place et dans des essais en collaboration, il est nécessaire que leur fonctionnalité et leur déploiement soient documentés Ce texte décrit les outils destinés aux utilisateurs potentiels, précise la procédure de lancement de chaque système et fait ressortir les applications acoustiques de type courant

This page is left blank

This page is left blank

P517364.PDF [Page: 8 of 32]

Executive summary

During the past few years, the Environmental Acoustics group has developed and/or acquired a number of large scale, purpose built systems to support underwater acoustics research at DREA. The systems fall into two categories: those used to make acoustic measurements of the parameters of interest, and those used to make environmental support measurements. The tool set described within has enabled the Environmental Acoustics group to measure a broad range of parameters required for sonar modelling, performance prediction, and future sonar development. A non-exhaustive list of acoustic parameters of interest includes monostatic and bistatic acoustic scatter from the seabed and sea surface, acoustic propagation and the impact of internal waves on propagation, ambient noise directionality, and geotechnical properties of the seabed. Due to the size and complexity of these systems and their potential use both in-house and in collaborative trials it is important that their functionality and deployment be documented. This memorandum describes these tools for potential users, outlines the launch procedure for each system, and highlights some typical acoustic applications.

Hines, Paul C., Osler, John C., Hutt, Daniel L. 2001. The Environmental Acoustics Group's Seagoing Measurement Systems. DREA TM 2001-173. Defence Research Establishment Atlantic.

?517364.PDF [Page: 9 of 32]

Sommaire

Au cours des dernières années, le groupe de l'acoustique environnementale a mis au point ou acquis un certain nombre de systèmes sur mesure à grande échelle dans le but d'appuyer les activités de recherche au CRDA Les systèmes sont regroupés dans deux catégories, soit les systèmes utilisés pour effectuer des mesures acoustiques des paramètres d'intérêt, et les systèmes utilisés pour prendre des mesures à l'appui des activités environnementales L'ensemble d'outils décrit ci-après a permis au groupe de l'acoustique environnementale de mesurer un vaste éventail de paramètres requis pour la modélisation par sonar, la prévision de la performance ainsi que l'élaboration de sonars à venir Une liste non exhaustive des paramètres acoustiques d'intérêt comprend la diffusion imputable au fond marin et à la surface de la mer, la propagation des ondes sonores et l'incidence des vagues internes sur la propagation, la directivité du bruit ambiant et les propriétés géotechniques du fond marin En raison de la taille et de la complexité des systèmes et de leur utilisation potentielle à la fois sur place et dans des essais en collaboration, il est nécessaire que leur fonctionnalité et leur déploiement soient documentés Ce texte décrit les outils destinés aux utilisateurs potentiels, précise la procédure de lancement de chaque système et fait ressortir les applications acoustiques de type courant

Hines, Paul C , Osler, John C , Hutt, Daniel L 2001 Systèmes de mesure en mer du groupe de l'acoustique environnementale CRDA TM 2001-173 Centre de recherches pour la défense Atlantique

Table of contents

Abstract			i
Executive summary			iii
Sommaire			iv
Table of contents			v
List of figures			vii
1	Introduction		1
2	System Descriptions		1
	2.1	The Wide Band Sonar (WBS)	2
	2.2	The Underwater Acoustic Target (UAT)	4
	2.3	The Sub-bottom Acoustic Profiler	5
	2.4	The Acoustic Localization Kit (ALK)	5
	2.5	Acoustic Doppler Current Profiler (ADCP)	6
	2.6	The Seahorse Moored CTD profiler	6
	2.7	The Seabird Shipborne CTD profiler	7
	2.8	The Free-falling Cone Penetrometer Test (FFCPT)	8
3	General Launch Procedure		9
	3.1	WBS Deployment Procedure	9
	3.2	UAT Deployment Procedure	10
	3.3	The Sub-bottom Acoustic Profiler Deployment	10
	3.4	The Acoustic Localization Kit (ALK) Deployment	11
	3.5	Acoustic Doppler Current Profiler (ADCP) Deployment	11
	3.6	The Seahorse Moored CTD profiler Deployment	11
	3.7	The Seabird Shipborne CTD profiler	12
	3.8	The Free-falling Cone Penetrometer Test (FFCPT)	12
4	A Sample of Typical Experiments and Experimental Geometries		13
	4.1	Direct measurements of scattering and bottom loss	13

7364.PDF [Page: 11 of 32]

4.2 Seabed classification using the UAT . 14
4.3 Wide angle reflection and bottom loss experiment 16

5 Concluding remarks 16

6 References 16

List of symbols/abbreviations/acronyms/initialisms 17

P517364.PDF [Page: 12 of 32]

List of figures

Figure 1 Schematic of Wide Band Sonar bottom-tethered (left), bottom-mounted (right) Note that the pivot point for the sonar support arm is different for the two configurations 3

Figure 2 Schematic of UAT free-drifting (left) and bottom-tethered (right) 3

Figure 3 Photograph of catamaran housing for the sub-bottom profiler acoustic source The source is the black circular disc 4

Figure 4 Components of the Acoustic Localization Kit a) deck command unit, b) tow fish with interrogation transducer, and c) two transponders with flotation 5

Figure 5 Photograph of ADCP system with transducer array packaged in the Streamlined Underwater Buoyancy System (SUBS) Shown on the right is a (simplified) mooring diagram for 75 m water depth 6

Figure 6 Schematic of Seahorse deployment configuration including DREA Met station on surface float (left) Seahorse on deck of Quest after recovery (right) 7

Figure 7 Sea-Bird Electronics, Inc SBE-25 SEALOGGER CTD (left) CTD being deployed from Quest oceanographic winch 8

Figure 8 FFCPT schematic diagram 9

Figure 9 Cross-section schematic of typical geometry for monostatic and bistatic scatter experiments 13

Figure 10 Geometry for seabed classification experiment 15

Figure 11 Geometry for WARBLE experiment from [4] 15

1. Introduction

The principal mandate of the Environmental Acoustics group is to enhance current sonar performance and support future sonar developments in support of CF requirements. This is done primarily by advancing our understanding of the effect of the environment on sonar signals. Doing this requires a substantial set of experimental tools. In addition to the acoustic measurements of principal interest, one must also measure geophysical and geotechnical properties of the seabed, and environmental conditions such as sound speed, wind speed, and sea surface roughness to name but a few.

During the past few years, the Environmental Acoustics group has developed or purchased a number of large scale purpose built systems to support underwater acoustics research at DREA. These systems have significantly enhanced the group's capability to carry out its mandate.

Due to the size and complexity of these systems and their potential use both in-house and in collaborative trials it is important to identify general launch procedures and typical experimental scenarios. The aim of this memorandum is to document these tools for potential users, outline the general launch procedure for each system, and highlight some typical acoustic applications.

2. System Descriptions

Seven main systems comprise the measurement tool set:

1. The Wide Band Sonar (WBS)
2. The Underwater Acoustic Target (UAT)
3. The Sub-bottom Acoustic Profiler
4. The Acoustic Localization Kit (ALK)
5. The Acoustic Doppler Current Profiler (ADCP)
6. The Seahorse Moored CTD profiler
7. The Sea-bird Shipborne CTD profiler
8. The Free-falling Cone Penetrometer Test (FFCPT)

Items 1, 2, and 3 are used to make fundamental acoustic measurements. Item 4 is used to measure experimental geometry for data interpretation. Items 5, 6, 7, and 8 are used to collect supporting environmental measurements. In the remainder of this section each of the systems will be described.

P517364.PDF [Page: 14 of 32]

2.1 The Wide Band Sonar (WBS)

The WBS is an active sonar used to collect acoustic data in the open ocean [1] The system employs a parametric array transmitter which enables direct measurement of seabed parameters in shallow water To complement the parametric transmitter, a pair of 6-channel receivers have been developed for the system, a 6-channel superdirective line array is used as the principle receiver and a tri-axial intensity array is used to localize the platform during bistatic experiments and to measure ambient noise directionality

The sonar's direction is remotely controlled from a research ship via an RF radio link fixed to the system's surface float This minimizes the risk of acoustic interference from the ship and prevents ship motion from compromising array stability In addition to acoustic sensors, the array is instrumented with a range of non-acoustic sensors to assist in the evaluation of the data The non-acoustic sensors include depth, tilt, roll, and heading sensors to monitor array position and direction, as well as accelerometers to monitor platform vibration The sonar head can be panned through 360° azimuth The array can be configured to be either bottom-tethered or bottom-mounted (Figure 1) In bottom-tethered mode the sonar support arm rotates 180° vertically so that the sonar can be positioned above or below the space frame This enables measurements through 4π steradians Platform stability is achieved by de-coupling the space frame from the surface float through a weighted cable and streaming the space frame into the prevailing shear current In bottom-mounted mode a remote command is sent from the ship to the surface float to flood the sub-surface floats on the space frame thereby setting the system on the seabed This offers an extremely stable platform that permits coherent averaging of multiple pings This is used in conditions of low signal-to-noise (SNR) such as measurements of backscattering strength at very shallow grazing angles, however, physical constraints limit the vertical range of angles to -30° from the horizontal up to+90° Prior to recovery compressed air is forced into the sub-surface floats to evacuate the water

The acoustic sensor suite consists of a parametric array transmitter (PATS), a superdirective endfire line array receiver (SIREM), and a tri-axial intensity array receiver (SIRA) The parametric array offers three advantages First and foremost, due to the nature of signal generation in the parametric array, no sidelobes are formed This feature avoids the added complexities of boundary interactions when making measurements in shallow water Second, one can obtain a wider bandwidth than that obtained using a conventional source In the present case a usable bandwidth of 1 kHz to 10 kHz is realized from a single transducer Third, the beamwidth of the parametric array is only 3° thereby allowing measurements of backscatter as a function of azimuth as well as out of plane bistatic scatter The principle receiver for measuring acoustic backscatter is the SIREM line array mounted on the PATS head The array yields gains of up to 15 dB across the sonar's frequency band from an array aperture only 0 8 m long The SIRA intensity array is a secondary receiver and is used to measure ambient noise directionality The superdirective array weights can then be optimized for the specific ambient noise field SIRA is also used to localize the platform during bistatic experiments It's bearing accuracy is better than ±0 5°

R517364 PDF [Page: 15 of 32]

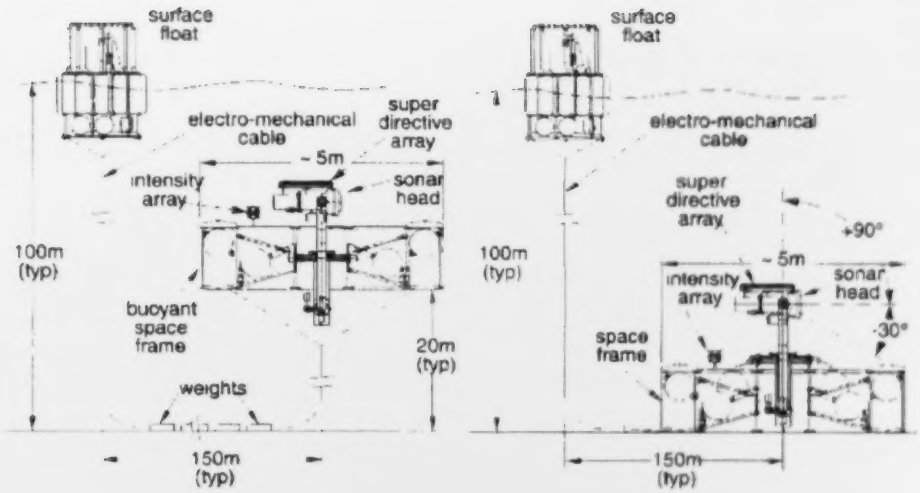

Figure 1 Schematic of Wide Band Sonar bottom-tethered (left) bottom-mounted (right) Note that the pivot point for the sonar support arm is different for the two configurations

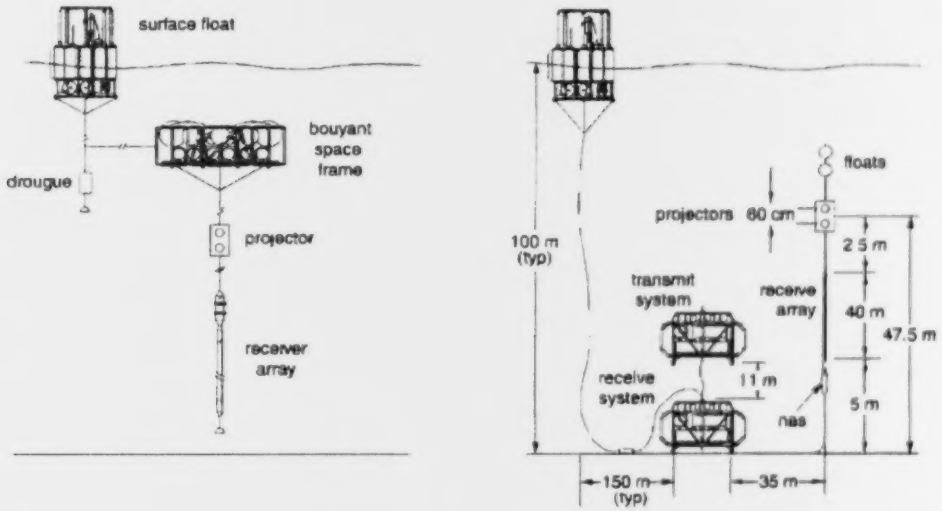

Figure 2 Schematic of UAT free-drifting (left) and bottom-tethered (right)

2.2 The Underwater Acoustic Target (UAT)

The UAT is a ship-launched echo-repeater with a 15 hydrophone vertical line array (VLA) and a non-acoustic section (NAS) suspended beneath the projectors. The array is kept vertical in the water by tensioning it with several sub-surface floats fixed to the upper end of the array. Data can be recorded by the system directly or can be telemetered back to the tending ship - the latter being the preferred and typical mode of operation. The projectors are controlled individually but may be used in tandem with user specified time and phase delays. Several projector options are available including a pair of 16 cm diameter spherical transducers operational from 3-15 kHz, as well as pairs of free-flooding rings for either the 1-4 kHz band or the 4-10 kHz band. Up to 8 hydrophones can be recorded simultaneously but must be selected prior to deployment. In echo-repeat mode, the UAT is used to simulate a target. The target strength, virtual Doppler speed of the target, and time delay prior to re-transmit (including an option for zero delay) are user defined, these settings can be pre-programmed or downloaded to the UAT via a command link. With echo-repeat mode disabled, the UAT functions as a remotely controlled source and receiver.

The UAT can be deployed free-drifting or bottom-tethered (See Figure 2). In bottom tethered mode the power and electronics modules for the UAT are housed in two space frames, for the transmit and receive systems respectively. This packaging arrangement is required to enable the system to be launched from the well deck of DREA's research vessel CFAV Quest. The space frames are displaced as far as possible horizontally from the VLA to minimize their influence on acoustic measurements in the vicinity of the array. In free drifting mode, all electronics are contained in a single space frame and the launch must be conducted from the Quarterdeck of CFAV Quest.

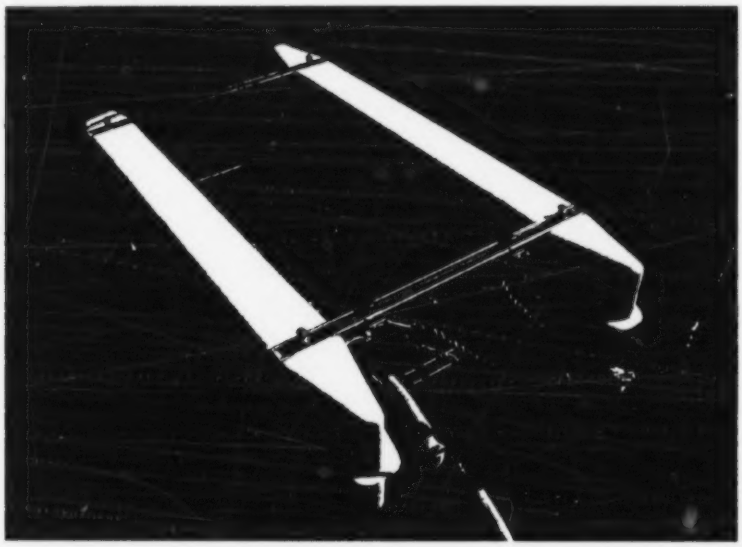

Figure 3 Photograph of catamaran housing for the sub-bottom profiler acoustic source. The source is the black circular disc.

2.3 The Sub-bottom Acoustic Profiler

The Sub-bottom Acoustic Profiler system, manufactured by GeoAcoustics Ltd , www.geoacoustics.com/specs/PDF_Files/GeoPulse_Boomer.pdf, consists of a surface towed broadband impulsive acoustic source and a towed array of hydrophones that receive the energy reflected from the seabed and sub-seabed layers As it operates in the same frequency band as the WBS (section 2.1), it is a useful instrument for characterizing the surficial geology in an experimental area The source, a 20 cm diameter boomer plate, is mounted in a 1.5 m long catamaran and towed by the research ship The boomer plate itself is towed at a depth of 15 to 20 cm below the sea surface (the minimum depth is 10 cm and maximum depth is 10 m) The pulse length is less than 0.2 ms, the bandwidth is approximately 1 to 10 kHz, and the source level is 227 re 1µPa @ 1m for the maximum input energy setting of 280 J The hydrophone array is 7.6 m long and 2 cm in diameter It contains 20 Benthos AQ-4 hydrophones with a sensitivity of -202 dB re 1 V/µPa Figure 3 contains a photograph of the catamaran that houses the sub-bottom profiler source

2.4 The Acoustic Localization Kit (ALK)

The ALK is used to determine the latitude, longitude, and depth of up to four acoustic transponders (beacons) that are fixed to sub-surface equipment such as the UAT and WBS space frames The research vessel tows a 10 kHz interrogation transducer mounted in a V-fin depressor (batfish) at 4 to 6 knots (Figure 4) The lay back and depth of the interrogation transducer may be configured based on the sound speed profile, but a tow depth of 5 m is typical The interrogation transducer receives slant range information from the individual beacons, at distinct frequencies from 9 to 12 kHz The received data is fed into a LabVIEW ™ program and this, coupled with GPS location information, is used to estimate the depth and absolute horizontal coordinates Localization can be done in real time or in playback mode In playback mode, data outliers can be discarded to improve the estimate Localization to within ±5 m is typical

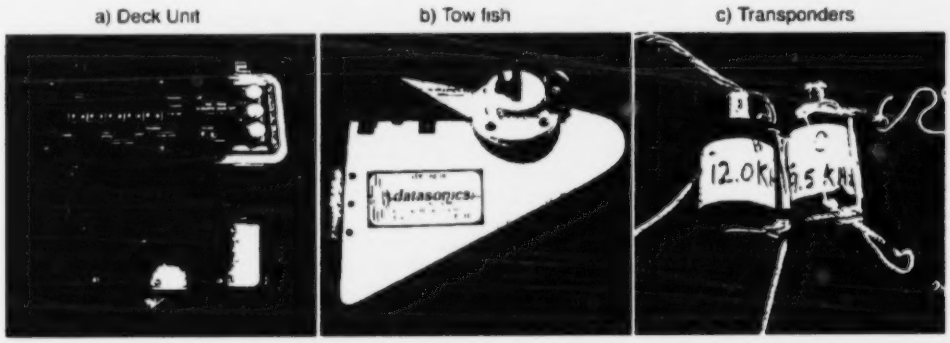

Figure 4 Components of the Acoustic Localization Kit a) deck command unit, b) tow fish with interrogation transducer, and c) two transponders with flotation

P517364.PDF [Page: 18 of 32]

2.5 Acoustic Doppler Current Profiler (ADCP)

RD Instruments Model WHS300 "Workhorse Sentinel" 300 kHz SC ADCP is a stand-alone instrument that measures ocean current speed and direction as a function of depth in the water column DREA has two of these instruments, each fitted with additional firmware to enable surface wave spectra to be measured

The ADCPs are cylindrical instrument packages 40 cm long by 23 cm in diameter with a mass of 13 kg They must be installed in a buoyant structure called a "Streamlined Underwater Buoyancy System" (SUBS) that is tethered 1 to 3 m from the seabed Figure 5 shows a photograph of the SUBS with the ADCP installed The SUBS is lowered to the seabed with anchor, tether line and surface buoy The instruments measure their tilt angle and will function at tilt angles up to 15 degrees A steel cable is attached to the anchor and to a float at the surface The instruments measure at depths up to 175 m although the pressure housings are rated for 500 m The ADCPs can be left to make measurements at pre-programmed intervals for periods up to 1 month The data are recorded in on-board solid-state memory modules Data are retrieved upon recovery

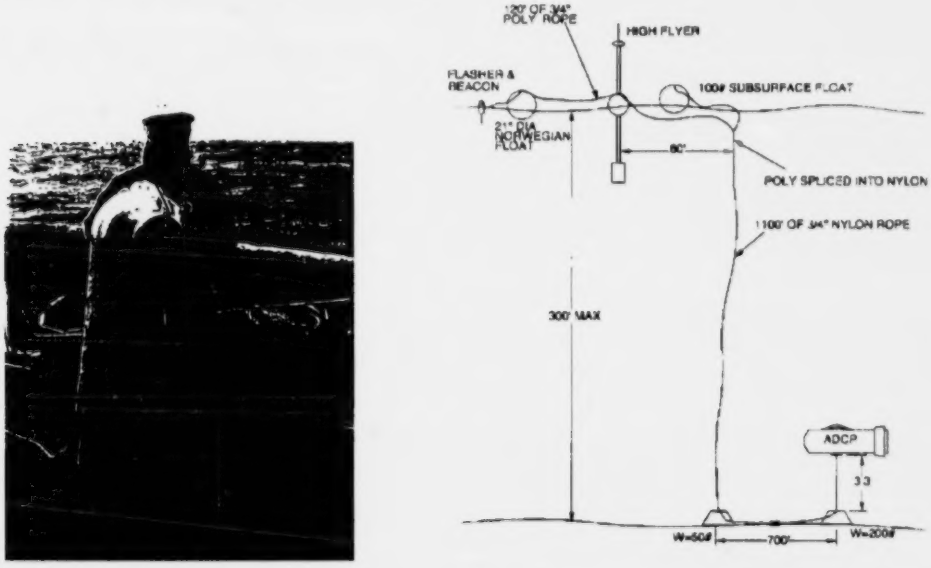

Figure 5 Photograph of ADCP system with transducer array packaged in the Streamlined Underwater Buoyancy System (SUBS) Shown on the right is a (simplified) mooring diagram for 75 m water depth

2.6 The Seahorse Moored CTD profiler

The Seahorse is an autonomous profiling system for continuous CTD measurements of the water column It is manufactured by Brooke Ocean Technology Ltd of Dartmouth, Nova Scotia, Canada The Seahorse sensor package is a Sea-Bird SBE-19 CTD The Seahorse rides along a cable between a surface float and a mooring anchor The Seahorse is designed for use to depths of 200 m The system takes advantage of the wave-induced motion of its surface

float to ratchet itself down the cable When the Seahorse reaches a stop at the bottom of the cable it waits for a programmed period of time then releases the ratchet mechanism and floats upward using the cable as a guide The CTD profile is acquired during the ascent

The Seahorse, is approximately 1 0 m by 0 6 m by 0 4 m with a mass of 52 kg The cable is 1/4-inch diameter coated steel and is attached to a 300 kg train wheel The surface float has a buoyancy of 10,000 N (2200 lbs) A schematic of the deployed configuration is shown in Figure 6 Sea surface meteorological measurements can be made with a meteorological (met) station located on the Seahorse buoy The met station is manufactured by MetOcean Inc of Dartmouth, Nova Scotia, Canada Measured parameters are wind speed and direction, air temperature, and water temperature Data are stored every minute in FlashCard memory and are retrieved upon recovery of the buoy The DREA met station is designed to support additional sensors in the future, including a sonic anemometer and optical precipitation gauge The system is also upgradeable to ARGOS or OrbComm satellite telemetry

Figure 6 Schematic of Seahorse deployment configuration including DREA Met station on surface float (left) Seahorse on deck of Quest after recovery (right)

2.7 The Seabird Shipborne CTD profiler

The Seabird SBE-25 CTD is a self-contained data logger for measurement of temperature and conductivity profiles in the water column (Figure 7) The instrument is portable, approximately 1 m long and weighs 20 kg The data are recorded internally and downloaded to a PC computer upon recovery In addition to the internal recording, the data may also be transmitted via an electro- mechanical cable Measurements are acquired continuously at a rate of 8 samples per second while the CTD is lowered on a cable, at a rate not to exceed 1 m/s, until it is within 5 m of the seabed The real-time telemetry option is particularly useful

?517364.PDF [Page: 20 of 32]

to monitor the depth of the instrument and avoid striking bottom when measurements near the seabed are required

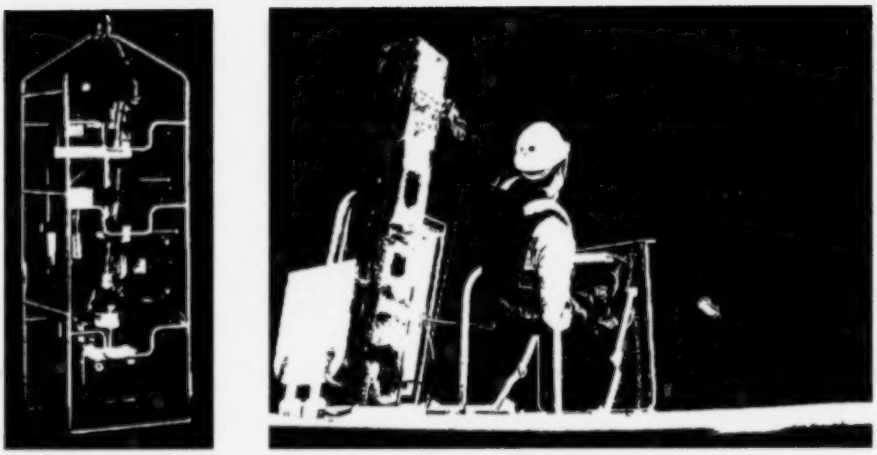

Figure 7 Sea-Bird Electronics, Inc SBE-25 SEALOGGER CTD (left) CTD being deployed from Quest oceanographic winch

2.8 The Free-falling Cone Penetrometer Test (FFCPT)

The FFCPT is a free fall probe that has been developed to measure depth-discretized geotechnical and geoacoustic properties of the seabed Specifically, it measures acceleration, dynamic sediment porewater pressure, hydrostatic pressure in the water, and has an optical backscatter sensor for mud line detection This combination of sensors represents a significant advance over acceleration-based penetrometers, such as the expendable bottom penetrometer (XBP) and permits the direct application of geotechnical analysis methods and parametric-based correlations already long established in engineering practice The DREA FFCPT has been developed under contract by Brooke Ocean Technology (BOT) Ltd (Dartmouth, Nova Scotia) It incorporates the basic sensor suite from a 4 5 inch O D BOT prototype into a modular 3 5 inch O D design that allows additional sensor payloads to be integrated (Figure 8) The first optional geoacoustic module being developed measures resistivity as a means to determine sediment bulk density Future modules may include a shaker, from which the shear rigidity of the seabed cab be determined, and a module for direct measurement of compressional sound speed The length of the probe and its weight are a function of the modules that are selected, but a weight of 40 kg and length of 1 5 m is typical

The FFCPT provides two independent means of calculating the undrained shear strength, one using the dynamic penetration resistance as measured using the accelerometer sensors and another using the dynamic porewater pressure response as measured by the sediment porewater pressure sensor A primary advantage of the FFCPT is that it uses a standard CPT-based sediment classification chart as part of the interpretation algorithm Specifically, it

employs accepted empirical relationships between the dynamic pore pressure parameter, the normalized dynamic penetration resistance, and sediment grain size characteristics

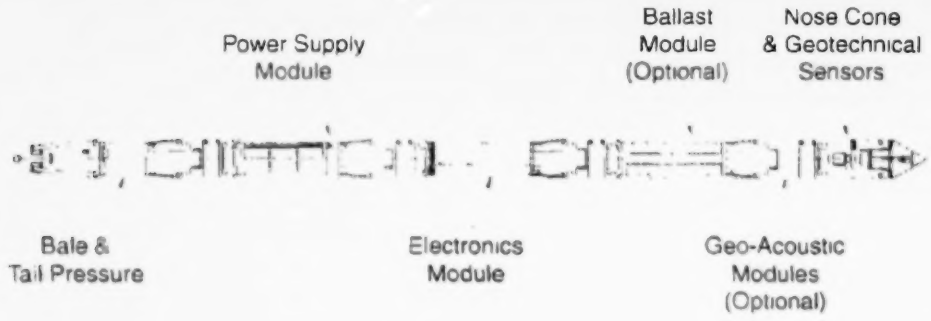

Figure 8 FFCPT schematic diagram

3. General Launch Procedure

During a typical environmental acoustics trial, all eight research systems described above are deployed Given the size and complexity of these systems, it is imperative that an efficient launch procedure be developed This is true not only from a safety perspective but also to ensure there is sufficient deck space to handle all systems and to maximize time for data collection on station In this section the general launch procedure for each system is highlighted

3.1 WBS Deployment Procedure

As shown in Figure 1, the WBS consists of a surface buoy, a weighted, double-armoured, electro-mechanical cable, and a positively buoyant sub-surface space frame The system is designed to ensure platform stability, a key factor in the performance of the sonar

The sonar head, power supplies, and electronics are supported on the hexagonal, aluminum, space frame which measures approximately 5 m across the flats by 1 4 m high Sub-surface floats are positioned to make the space frame positively buoyant with its top surface horizontal Prior to deployment, two of the sides are extended with fabric panels These stream the platform into the prevailing shear current The complete platform assembly weighs approximately 40 kN (8900 lbs) in air In bottom tethered mode, the platform is ballasted to have about 0 45 kN (100 lbs) of positive buoyancy whereas in bottom-mounted mode, it is about 4 5 kN (1000 lbs) negatively bouyant once the sub-surface floats are flooded

P517364.PDF [Page: 22 of 32]

The space frame is connected to a surface float via an armoured electro-mechanical cable, with ancillary weights over part of its length. The weighted portion, which lies along the bottom, serves two purposes. It sets the height to which the buoyant platform will rise, and it isolates the platform from motions of the surface float.

With CFAV Quest drifting, the space frame is lifted over the port side of the ship's quarterdeck and released from the crane. Then, as the vessel drifts away downwind, the electromechanical cable attached to the bottom of the structure is paid off a cable reeler. The weight of the cable loop between ship and space frame slowly sinks the space frame. Finally, the surface float is affixed and released over the side. armored cable is used because there is a short period during which the cable is dragged across the bottom while the surface float is being attached. Due to the mass and cross-sectional area of the WBS, deployments must be carried out in relatively low sea states with winds less than about 15 kt. The typical time for deployment or recovery is approximately 90 minutes.

3.2 UAT Deployment Procedure

The vertical line array (VLA) of hydrophones is housed in a 40 m long, oil-filled polyurethane hose with a 6 cm outside diameter. The transmitters are shrouded in a 120 litre barrel that is open at both ends. With CFAV Quest drifting, the VLA – which includes the transmitters and sub-surface tensioning floats – is deployed by hand over the starboard side of the ship's welldeck. This is tied off to the ship to enable the load transfer to the winch cable. The receiver space frame (which is neutrally buoyant) is launched using the well deck crane and drifts along with the ship while the crane is positioned to launch the (positively buoyant) transmitter space frame. Once the transmitter space frame is deployed, the line holding the array is released and the electromechanical cable is spooled into the water. The weight of the cable loop between the ship and the space frames slowly sinks both space frames. Finally, the surface float is affixed to the termination of the electro-mechanical cable and released over the side. armoured cable is used because there is a short period during which the cable is dragged across the bottom while the surface float is being attached. Due to the size and the mechanical complexity of the system, deployments must be carried out in relatively low sea states with winds less than about 15 kt. Typical deployment (or recovery) time is approximately 120 minutes.

When the UAT operates in free drifting mode, all electronics are contained in a single space frame and the launch must be conducted from the Quarterdeck of CFAV Quest. In this case the launch procedure is essentially the same as that of the WBS.

3.3 The Sub-bottom Acoustic Profiler Deployment

The sub-bottom profiler system consists of a surface towed broadband impulsive acoustic source and a separate 7.6 m long towed hydrophone array. The hydrophones are housed in an oil filled hose 2 cm in diameter. The catamaran (shown in Figure 3) is deployed using the quarterdeck A-frame with Quest proceeding at approximately 3-4 knots. There is a separate high voltage power cable that runs from the power supply into the Quest Dry Lab, across the quarterdeck, to the catamaran. During normal operations, the catamaran is towed approximately 15 m astern of Quest at 4 to 5 knots. The hydrophone array is deployed by

hand through one of the Port or Starboard hawseholes It is towed just below the surface at approximately the same distance astern as the catamaran such that it is not in the wake of the vessel Lead shot may be added to the tow cable forward of the fairing from the tow cable to the hydrophone array in order to achieve the desired tow depth The remaining hydrophone array tow cable is run to the data acquisition system in the Quest Dry Lab Deployment and recovery times are about 20 minutes each

3.4 The Acoustic Localization Kit (ALK) Deployment

The ALK interrogation transducer is mounted in a V-fin depressor known as a batfish The batfish tow cable is fed through a pulley on the Quarterdeck A-Frame The A-Frame is lowered slightly to achieve an acceptable lay-back for the batfish The required lay-back and depth required for the interrogation transducer depends on the sound speed profile, but a tow depth of 5 m is typical Deployment is done with the ship steaming at 4-5 knots The remaining tow cable is run to the deck unit in the Quest Dry Lab Localization experiments are performed at a tow speed of about 6 knots Estimated deployment or recovery time is 15 minutes

3.5 Acoustic Doppler Current Profiler (ADCP) Deployment

The ADCP in the SUBS enclosure is anchored to the seabed with a 200 lb weight as shown in Fig 5 The mooring rope is wound around a reeler and deployment begins by lowering the anchor weight and ADCP over the port side fairlead of the ship while the ship is drifting with wind to port side Once the ADCP is just below the sea surface and can be seen to be tangle free, the mooring line is paid off the reeler until the anchor weight reaches the bottom The ADCP is pulled down by the weight and remains floating above it The remainder of the mooring line is paid out at a rate equal to the ship's drift rate The subsurface float, high flyer, Norwegian float and beacon/flasher assembly are attached to the recovery line in the appropriate place prior to going over the side The mooring line is paid out at a constant rate until all the components are deployed Recovery of the ADCP mooring is done in reverse order where the ship approaches the line between the Norwegian float and high flyer to grapple it from the bow and wind it onto the reeler while detaching all associated hardware Deployment or recovery time is approximately 30 minutes

3.6 The Seahorse Moored CTD profiler Deployment

A schematic of the Seahorse mooring is shown in Fig 6 Using the aft crane, the train wheel anchor is first lifted over the port side of the ship and secured to hang there temporarily Then some mooring cable is paid off the reeler and flaked out on the deck Next, the mooring cable is attached to the surface float and then the Seahorse is attached to the mooring cable and is ready for deployment The mooring cable has particular characteristics for use with the Seahorse ratcheting mechanism It is 1/4" galvanized steel wire rope, with a polypropylene jacket, 5/16" outside diameter

With the wind to the port side of the ship, the surface float is put over the port side with the aid of the crane and allowed to drift away from the ship When the surface float is free of the ship the Seahorse is then deployed by hand over the side The remainder of the anchor system is payed out at the ship's drift rate When the attachment point for the anchor weight arrives it is joined and the weight is released The cable is paid off the reeler until the anchor reaches

bottom The Seahorse instrument may remain near the surface due to it's positive buoyancy The remainder of the mooring line is paid out at a rate equal to the ship's drift rate The subsurface float, high flyer, Norwegian float and beacon/flasher assembly are attached to the recovery line in the appropriate place prior to going over the side The mooring line is paid out at a constant rate until all the components are deployed Recovery of the Seahorse mooring is done in reverse order where the ship approaches the recovery line (not shown in Figure 6) between the Norwegian float and high flyer to grapple it from the bow and wind it onto the reeler and detaching all associated hardware Deployment or recovery time is approximately 45 minutes

3.7 The Seabird Shipborne CTD profiler

The CTD is a relatively small instrument that is deployed when the ship has come to a full stop The General Purpose Oceanographic (GPO) winch is the preferred location for its deployment as it is sheltered from the elements and provides a dedicated space for the instrument However, other winches or reelers may be used if the GPO winch is unavailable The CTD can be deployed on a rope and operate in a self-contained mode It can also telemeter its data to a PC if it is deployed using an electro-mechanical cable Damage may result if the CTD hits bottom so it is typically kept at least 5 m above the seabed When operating in self-contained mode, a metered block is used to measure the amount of cable out, but it can be difficult to estimate the appropriate correction for the wire angle When connected to an electro-mechanical cable, the maximum depth can be controlled using the reading from the instrument's pressure sensor A weight is of often hung below the CTD or attached to the stainless steel cage to minimize the wire angle On occasion, a PVC water sample bottle may be attached to the deployment cable or rope to obtain a water sample to calibrate the CTD *Note that the CTD must be held immediately below the surface for 1 minute before lowering in order to activate a submerged pump.* Estimated time for a CTD cast, in less than 100 m of water, is 20 minutes

3.8 The Free-falling Cone Penetrometer Test (FFCPT)

The FFCPT may be deployed from either the well deck or quarterdeck A recovery line is connected to the bale on the tail of the instrument, passes through a snatch block held by a crane and is wound on a cable reeler The probe must free-fall into the seabed so it is lowered to some depth below the surface with the load held by another tether line that has been looped through the bale A length of recovery line that is sufficient to allow the instrument to free-fall from its launch to the seabed is coiled and held overboard Upon command of the bosun, the probe is launched by releasing the tether line and dropping the coils of recovery into the water The FFCPT must be left in the seabed for 30 s to complete the measurement and is then recovered In between drops, it is stored in a bucket of water to prevent air from entering the pore pressure sensor located immediately after the nose cone

Before the initial deployment, the probe is acclimated by suspending it at mid-water depth for at least 15 minutes It is then lowered to the seabed to calibrate the depth sensor, recovered, and prepared for the first free-fall drop If the probe penetrates deeply on a soft bottom, the pull-out loads can be several times the intrinsic weight of the probe Estimated deployment or recovery time per drop is 15 minutes plus 30 minutes for the initial setup and acclimation

4. A Sample of Typical Experiments and Experimental Geometries

The acoustic and environmental measurement tool set described above has enabled the Environmental Acoustics group to measure a broad range of parameters required for sonar *modeling and future sonar development*. *The support tools (items 4 - 8 listed in Section 2)* are used to collect environmental information needed for interpretation and modeling of the acoustic measurements). A non-exhaustive list of acoustic parameters of interest includes monostatic and bistatic acoustic scatter from the seabed and sea surface, acoustic propagation, ambient noise directionality, and frequency, angle, and time spreading of acoustic signals. In this section typical acoustic experiments designed to measure some of these parameters are presented. The list is by no means all-inclusive but it does serve to highlight the capability of the systems.

4.1 Direct measurements of scattering and bottom loss

Direct measurements of acoustic backscatter and forward scatter from the seabed at sub-critical grazing angles presents a considerable challenge in shallow water. Specifically, returns from the air-water interface typically contaminate the signal of interest. However, the absence of sidelobes on the WBS parametric array makes it an ideal source for making these measurements. Moreover, using the UAT in conjunction with the WBS allows one to obtain spatially and temporally coincident measurements of bottom loss, backscatter and forward scatter. Backscatter measurements are made on the WBS superdirective line array and bottom loss and forward scatter are measured on the UAT Vertical Line Array.

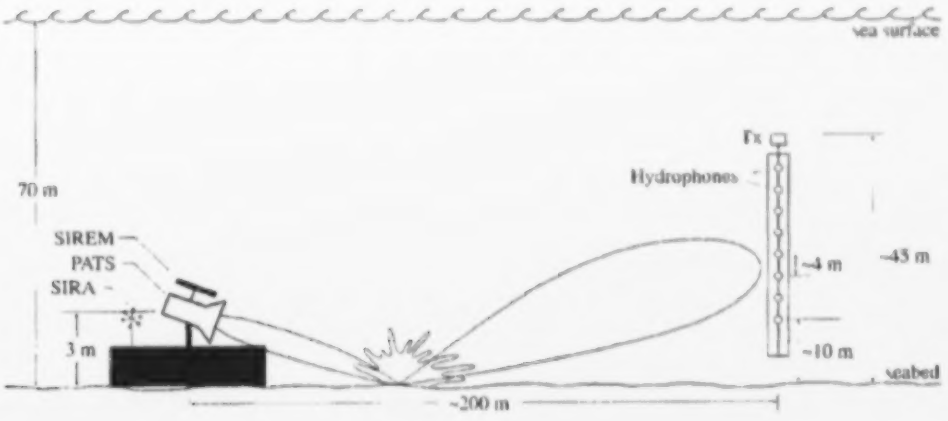

Figure 9 Cross-section schematic of typical geometry for monostatic and bistatic scatter experiments

The experimental geometry is a critical factor in this experiment. If the systems are too close (<100 m) the spatial resolution of the VLA is too coarse, if they are separated too far (>300 m) the VLA spans too narrow a vertical beam of angles. Noting that both systems weigh over 2000 kg, this is not a trivial concern. The UAT is launched first and an initial localization is

PS17364.PDF [Page: 26 of 32]

performed using the ALK. The ship then steams upwind and drifts back past the UAT location crossing within about 100 m of the UAT waypoint. During this trial run, the ship's drift vector is monitored. The space frame is readied on the ship's crane and the launch run commences. A delay of approximately 4 minutes occurs from the time the spaceframe is lifted off the deck to the time it is released into the water. This delay is accounted for during the deployment so that the spaceframe is released at CPA. Immediately after releasing the spaceframe, the weighted cable is rapidly winched into the water to avoid towing the system. Once deployed, the WBS is localized with the ALK and the acoustic experiments can proceed.

Figure 9 contains a schematic of the experimental geometry. The WBS is pointed at a grazing angle such that the specular reflection insonifies the center hydrophone of the VLA at an azimuth of about -15° relative to the vertical axis of the UAT array. A series of 50 pulses are transmitted by the WBS at 2, 4, and 8 kHz with a pulse repetition frequency (PRF) of 4 per second. Forward bistatic scatter is recorded on the UAT and backscatter is recorded on the WBS superdirective array. The parametric array transmitter is rotated 2° in azimuth and the sequence repeated out to a relative azimuth of +15°. This experiment yields measurements of vertical and horizontal scattering from the specular direction, as well as backscatter as a function of azimuth. Repeating the experiment at several grazing angles increases the vertical resolution of the forward scatter measurements. At various times throughout the experiment, the SIRA intensity array is switched in and the UAT transmits sets of fifty 4 kHz tone bursts, 0.5 ms in duration. These pulses are processed to localize the UAT as well as to quantify VLA motion.

4.2 Seabed classification using the UAT

It has been demonstrated that seabed classification systems that use the 1st and 2nd normal incidence fathometer returns take advantage of the fact that whereas the 1st return is monostatic, the 2nd return is bistatic [2]. Typically these systems operate in the range of several tens of kHz so that bottom roughness at the seabed interface is the dominant scattering mechanism. Recently, it has been shown that it should be possible to employ this technique at lower frequencies and take advantage of the frequency dependence of the scatter to discriminate between seabeds [3]. Furthermore, a vertical line array receiver would improve sediment classification considerably. The vertical aperture enables a series of measurements which would transition from near-field bistatic (using the hydrophone nearest the seabed) to far-field monostatic (using the hydrophone co-located with the projectors). In addition, the line array eliminates the requirement for the surface reflected path which is sea-state dependent. Furthermore, the arrival time of the bistatic returns to the individual elements can be used to differentiate interface scatter from sub-bottom scatter.

The geometry for seabed classification is shown in Figure 10. In this experiment the UAT transmits a series of short CW pulses (typically 1 to 10 ms duration) and the near-normal incidence backscatter from the seabed is recorded on the VLA. This experiment is performed at several frequencies in the 1-10 kHz band such that the VLA projector spacing corresponds to $(n+1/4)\lambda$ where n=0, 1, 2, or 3. The two projectors are driven in anti-phase with the upper projector having a time delay of $(n+1/4)\lambda$. This results in a cardioid shaped pulse (or aliased cardioid for $n \neq 0$) with a null directed at the surface for the entire duration of the pulse. If the UAT is free-drifting, one is afforded the opportunity to run the experiment over a variety of

P517364.PDF [Page: 27 of 32]

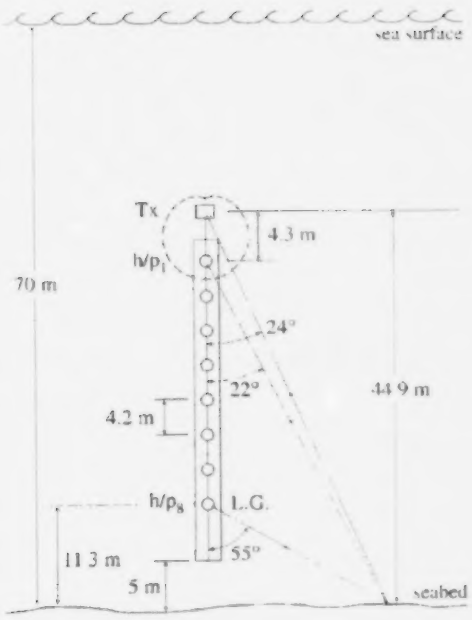

Figure 10 Geometry for seabed classification experiment

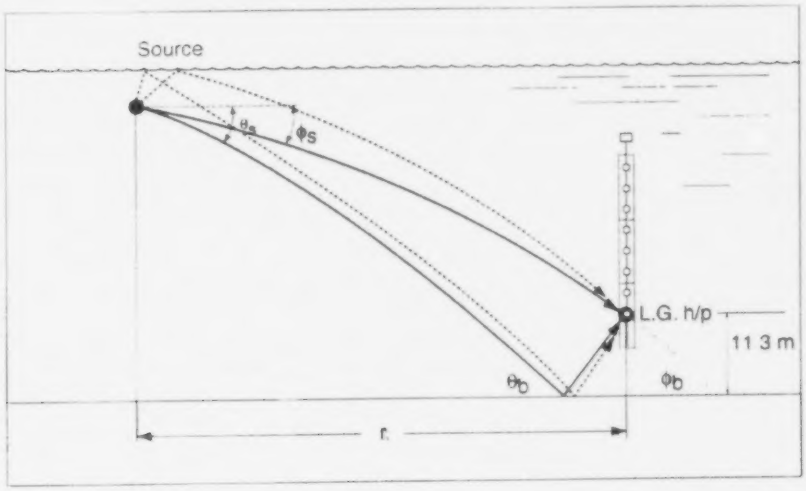

Figure 11 Geometry for WARBLE experiment from [4]

P517364.PDF [Page: 28 of 32]

seabed types. Note that pointing the transmitter null at the seabed rather than the sea surface enables one to measure backscatter and in-plane bistatic scatter from the sea surface.

4.3 Wide angle reflection and bottom loss experiment

Using the GeoAcoustics boomer as the acoustic source and a low gain hydrophone on the UAT as the receiver, the ship tows the source on orthogonal transects on top of the UAT Vertical Line Array position as determined using the ALK. The VLA is moored such that there is at least 10 to 15 m between the uppermost sub-surface float and the sea surface to allow clear passage of the vessel. The seismic reflection data that is obtained over a wide range of grazing angles may be inverted to determine the compressional sound speed data for the upper sediment column. The bottom reflection loss data may be used directly (as a model input) or further processed to extract sediment geoacoustic properties (e.g., sound speed, attenuation and density). Inherent in the technique is a calibration of the towed or hull-mounted source (Figure 11).

5. Concluding remarks

This memorandum describes the principal systems used by the Environmental Acoustics group to make at-sea measurements in support of current and future sonars. The tool set consists of both commercial off-the-self (COTS) systems and systems designed and built at DREA. To compliment the acoustic measurements, several of the systems measure key environmental parameters. This enables the acoustic data to be modelled and ultimately leads to enhanced sonar performance predictions. Taken collectively, the systems described within represent a world-class capability in underwater acoustics research.

6. References

1. Hines, Paul C., Risley, W. Cary, and O'Connor, Martin P., "A Wide-Band Sonar for Underwater Acoustics Measurements in Shallow Water," Proceedings Oceans'98, Nice, France, Sept. 29-Nov. 1, 1998.

2. Heald, G.J., and Pace, N.G., "An analysis of 1st and 2nd echoes for seabed classification," Proceedings 3rd European Conference on Underwater Acoustics, edited by J.S. Papadakis, Forth-IACM, Heraklion, 1996, pp. 649-654.

3. Hines, Paul C., and Heald, G.J., "Seabed classification using normal incidence backscatter measurements in the 1-10 kHz frequency band," Proceedings of the Institute of Acoustics Conference on Acoustical Oceanography, Southhampton, United Kingdom, 2001, vol. 23, Pt. 2, pp. 42-50.

4. Holland, C.W., and Osler, J., "High resolution geoacoustic inversion in shallow water: a joint time and frequency domain technique," Journal of the Acoustical Society of America, 107, 2000, pp. 1263-1279.

P517364.PDF [Page 29 of 32]

List of symbols/abbreviations/acronyms/initialisms

ADCP	Acoustic doppler current profiler
ALK	Acoustic localization kit
CPA	Closest point of approach
CTD	Conductivity-temperature-depth
CW	Continuous wave
DND	Department of National Defence
FFCPT	Free fall cone penetrometer test
GPO	General purpose oceanographic
PC	Personal computer
PRF	Pulse repetition frequency
SUBS	Streamlined underwater buoyancy system
UAT	Underwater acoustic target
VLA	Vertical line array
WBS	Wide band sonar

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1 ORIGINATOR (the name and address of the organization preparing the document Organizations for whom the document was prepared, e g Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8)

Defence Research Establishment Atlantic
P O Box 1012
Dartmouth, Nova Scotia B2Y 3Z7 Canada

2 SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable)

UNCLASSIFIED

3 TITLE (the complete document title as indicated on the title page Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title)

The Environmental Acoustics Group's Seagoing Measurement Systems

4 AUTHORS (Last name, first name, middle initial If military, show rank, e g Doe, Maj John E)

Hines, Paul C., John C. Osler, Daniel L Hutt

5 DATE OF PUBLICATION (month and year of publication of document)

October 2001

6a NO OF PAGES (total containing information Include Annexes, Appendices, etc)

27

6b NO OF REFS (total cited in document)

4

7 DESCRIPTIVE NOTES (the category of the document, e g technical report, technical note or memorandum If appropriate, enter the type of report, e g interim, progress, summary, annual or final Give the inclusive dates when a specific reporting period is covered)

Technical Memorandum

8 SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development Include address)

Defence Research Establishment Atlantic
PO Box 1012
Dartmouth, NS, Canada B2Y 3Z7

9a PROJECT OR GRANT NO (if appropriate, the applicable research and development project or grant number under which the document was written Please specify whether project or grant)

1ca11

9b CONTRACT NO (if appropriate, the applicable number under which the document was written)

10a ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity This number must be unique to this document)

DREA TM 2001-173

10b OTHER DOCUMENT NOs (Any other numbers which may be assigned this document either by the originator or by the sponsor)

11 DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

(X) Unlimited distribution
( ) Defence departments and defence contractors; further distribution only as approved
( ) Defence departments and Canadian defence contractors; further distribution only as approved
( ) Government departments and agencies; further distribution only as approved
( ) Defence departments; further distribution only as approved
( ) Other (please specify):

12 DOCUMENT ANNOUNCEMENT (any limitation to the bibliographic announcement of this document This will normally correspond to the Document Availability (11) However, where further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected)

13. ABSTRACT (a brief and factual summary of the document It may also appear elsewhere in the body of the document itself It is highly desirable that the abstract of classified documents be unclassified Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U) It is not necessary to include here abstracts in both official languages unless the text is bilingual)

During the past few years, the Environmental Acoustics group has developed and/or acquired a number of large scale, purpose built systems to support underwater acoustics research at DREA. The systems fall into two categories: those used to make acoustic measurements of the parameters of interest, and those used to make environmental support measurements. Due to the size and complexity of these systems and their potential use both in house and in collaborative trials it is important that their functionality and deployment be documented. This memorandum describes these tools for potential users, outlines the launch procedure for each system, and highlights typical acoustic applications.

14 KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document They should be selected so that no security classification is required Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included If possible keywords should be selected from a published thesaurus e g Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified If it not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title)

Underwater acoustics
acoustic measurement systems
wide band sonar
WBS
Underwater acoustic target
UAT